CLAIMS

1. A control device for a mobile body comprising desired motion determining means for determining a desired motion of the mobile body, such as a mobile robot, having three or more ground contact portions connected through the intermediary of a plurality of joints such that mutual relative heights can be manipulated, and actual posture inclination detecting means for detecting or estimating the actual posture inclination of a predetermined portion, such as a base body of the mobile body, the operation of the mobile body being controlled to make the motion of the mobile body follow a desired motion, further comprising:

node operation controlling means that categorizes the ground contact portions in a tree structure manner such that all of the ground contact portions become leaf nodes, and an intermediate node exists between the leaf nodes and a root node having all the leaf nodes as descendant nodes,

determines, on each of C-th nodes, which is a node having a plurality of ground contact portions as descendant nodes, the correction amounts of desired relative heights of a plurality of ground contact portions belonging to the C-th node for each of the C-th nodes such that a posture inclination error is approximated to zero on the basis of at least the posture inclination error, which is the difference between the actual posture inclination and a desired posture inclination of the

predetermined part in the desired motion, determines, on the basis of a correction amount obtained by combining the determined correction amounts of all the C-th nodes, a corrected desired motion by adding at least a first correction of the desired relative heights of the plurality of ground contact portions belonging to each C-th node to the desired motion, and operates the joints such that the corrected desired motion that has been determined is satisfied.

2. The control device for a mobile body according to Claim 1, wherein

if each node in the tree structure has a set weight, and regarding a B-th node, which is each node in the tree structure, if the B-th node is the leaf node, then the height of a ground contact portion, which is the leaf node, is defined as the height of the B-th node, and if the B-th node has child nodes, then a weighted mean value, which uses the weight, of the heights of all child nodes of the B-th node is defined as the height of the B-th node, and

if the node operation controlling means determines the corrected desired motion for only one arbitrary node among the C-th nodes by adding a first correction of the desired relative heights of the plurality of ground contact portions belonging to that one node to the desired motion, then the desired height of that one node in the corrected desired motion is maintained at a desired height in the desired motion.

3. A control device for a mobile body comprising desired motion determining means for determining a desired motion of the mobile body, such as a mobile robot, having three or more ground contact portions connected through the intermediary of a plurality of joints such that mutual relative heights can be manipulated, and actual posture inclination detecting means for detecting or estimating the actual posture inclination of a predetermined portion, such as a base body of the mobile body, the operation of the mobile body being controlled to make the motion of the mobile body follow a desired motion,

a weight being set for each node in a tree structure when the ground contact portions are categorized in the tree structure manner such that all of the ground contact portions become leaf nodes and an intermediate node exists between the leaf nodes and a root node having all the leaf nodes as descendant nodes,

the control device comprising a node operation controlling means that determines a corrected desired motion obtained by adding at least a first correction of desired relative heights of the plurality of ground contact portions belonging to the C-th node to the desired motion such that a posture inclination error is approximated to zero on the basis of at least the posture inclination error, which is the difference between the actual posture inclination and a desired posture inclination of the predetermined portion in the desired

motion, and operates the joints such that the corrected desired motion that has been determined is satisfied,

wherein, on a B-th node, which is each node in the tree structure, if the B-th node is the leaf node, then the height of the ground contact portion, which is the leaf node, is defined as the height of the B-th node, and if the B-th node has child nodes, then a weighted mean value, which uses the weight, of the heights of all child nodes of the B-th node, is defined as the height of the B-th node, and if the node operation controlling means determines the desired motion for only the C-th node by adding a first correction of the desired relative heights of the plurality of ground contact portions belonging to the C-th node to the desired motion, then the desired height of the C-th node in the corrected desired motion is maintained at a desired height in the desired motion.

4. The control device for a mobile body according to Claim 2 or 3, wherein, on each node having child nodes in the tree structure, the weights of all child nodes of the each node are set such that the total sum of the weights of all the child nodes becomes one.

5. The control device for a mobile body according to Claim 2 or 3, comprising means for variably setting the weight of the each node, wherein if leaf nodes corresponding to ground contact portions, respectively, that are not in contact with the ground are defined as D-th nodes, then the means for setting the weights sets the

weight of each D-node or the weight of at least one of ancestor nodes of the D-th node to zero.

6. The control device for a mobile body according to Claim 1 or 2,

wherein the ground contact portions are connected to the base body of the mobile body in such a manner that they are movable with respect to the base body, and

when determining the corrected desired motion, the node operation controlling means determines the corrected desired motion by further adding to the desired motion a correction of a desired posture of the base body to restrain slippage, such as twist, of the ground contact portions belonging to the C-th node on a floor surface.

7. The control device for a mobile body according to Claim 3,

wherein the ground contact portions are connected to the base body of the mobile body in such a manner that they are movable with respect to the base body, and

when determining the corrected desired motion, the node operation controlling means determines the corrected desired motion by further adding to the desired motion a correction of a desired posture of the base body to restrain slippage, such as twist, of the ground contact portions belonging to the C-th node on a floor surface.

8. The control device for a mobile body according to Claim 6 or 7, wherein the node operation controlling means determines the corrected desired motion such that the

horizontal position of the overall center-of-gravity of the mobile body in the corrected desired motion or the horizontal position of a predetermined representative point of the base body of the mobile body is substantially the same as the horizontal position in the desired motion.

9. The control device for a mobile body according to Claim 6, wherein the mobile body is a robot comprising a plurality of link mechanisms extended from its base body, and at least one link mechanism out of the plurality of link mechanisms has a joint provided at an intermediate portion between at least its distal portion and the end portion adjacent to the base body, the intermediate portion being the ground contact portion.

10. The control device for a mobile body according to Claim 7, wherein the mobile body is a robot comprising a plurality of link mechanisms extended from its base body, and at least one link mechanism out of the plurality of link mechanisms has a joint provided at an intermediate portion between at least its distal portion and the end portion adjacent to the base body, the intermediate portion being a ground contact portion belonging to the C-th node.

11. The control device for a mobile body according to Claim 9 or 10, wherein the intermediate portion is provided with an elastic member that resiliently deforms when it comes in contact with the ground.

12. The control device for a mobile body according to

Claim 6, wherein the mobile body comprises a plurality of link mechanisms which are extended from its base body and each of which has one or more joints, and at least one link mechanism among the plurality of link mechanisms and the base body are provided with the ground contact portions.

13. The control device for a mobile body according to Claim 7, wherein the mobile body comprises a plurality of link mechanisms which are extended from its base body and each of which has one or more joints, at least one link mechanism among the plurality of link mechanisms and the base body are provided with the ground contact portions, and ground contact portions belonging to the C-th node include at least the ground contact portions of the base body.

14. The control device for a mobile body according to Claim 12 or 13, wherein at least one ground contact portion of the base body is provided with an elastic member that resiliently deforms when it comes in contact with the ground.

15. The control device for a mobile body according to Claim 1 or 3, the ground contact portions being connected to the base body through the intermediary of connecting mechanisms such that they can be moved with respect to the base body of the mobile body, comprising:

means for determining a translational force component of a desired floor reaction force to be applied

to ground contact portions belonging to the C-th node when the joint is operated such that the corrected desired motion is satisfied,

wherein the node operation controlling means comprises a means for estimating a deformation amount that occurs at the connecting mechanisms between the base body and the ground contact portions belonging to the C-th node and the ground contact portions when the translational force component of the desired floor reaction force is applied to the ground contact portions belonging to the C-th node on the basis of the translational force components of the desired floor reaction forces of the ground contact portions belonging to at least the C-th node, and determines the corrected desired motion by further adding a second correction of the desired heights of the plurality of ground contact portions belonging to the C-th node, which is for canceling the estimated deformation amount, to the desired motion.

16. The control device for a mobile body according to Claim 1 or 3, comprising:

floor configuration estimating means for estimating a parameter that specifies the relative heights of the ground contact surfaces of a plurality of ground contact portions belonging to at least the C-th node as the floor configuration parameter that represents a floor configuration,

wherein the node operation controlling means

determines the corrected desired motion by further adding a third correction of the desired relative heights of a plurality of the ground contact portions belonging to the C-th node on the basis of an estimated value of a floor configuration parameter when determining the corrected desired motion.

17. The control device for a mobile body according to Claim 16, comprising:

floor reaction force detecting means for detecting or estimating an actual floor reaction force that acts on each of the ground contact portions,

wherein the floor configuration estimating means performs estimation while sequentially updating the floor configuration parameter on the basis of a past value of an estimated value of the floor configuration parameter, a difference between the corrected desired motion and the desired motion, the corrected motion, at least either a detected value or an estimated value of an actual joint displacement, which is a displacement amount of each joint of the mobile body, the actual posture inclination, and an actual floor reaction force of each of the ground contact portions belonging to at least the C-th node.

18. The control device for a mobile body according to Claim 16, comprising:

floor reaction force detecting means for detecting or estimating an actual floor reaction force that acts on each of the ground contact portions; and

means for sequentially determining at least an actual node floor reaction force, which is an actual value of the node floor reaction force of each child node of the C-th node, from the actual floor reaction force of each ground contact portion belonging to the C-th node if, regarding A-th nodes, which are the nodes in the tree structure, the A-th nodes are the leaf nodes, then the floor reaction forces acting on the ground contact portions, which are the leaf nodes, are defined as the node floor reaction forces of the A-th nodes, and if the A-th nodes have child nodes, then the resultant force of the node floor reaction forces of all the child nodes of the A-th nodes is defined as the node floor reaction force of the A-th nodes,

wherein the floor configuration estimating means performs estimation while sequentially updating the floor configuration parameter on the basis of the past value of an estimated value of the floor configuration parameter, the difference between the corrected desired motion and the desired motion, the corrected motion, at least either a detected value or an estimated value of an actual joint displacement, which is a displacement amount of each joint of the mobile body, the actual posture inclination, and a relative relationship among the actual node floor reaction forces of the child nodes of at least the C-th node.

19. The control device for a mobile body according to Claim 16, the ground contact portions being connected to

the base body through the intermediary of connecting mechanisms such that they are movable with respect to the base body of the mobile body, comprising:

deformation amount detecting means for detecting or estimating the amounts of deformations that occur at the connecting mechanisms between the base body and the ground contact portions and at the ground contact portions,

wherein the floor configuration estimating means performs estimation while sequentially updating the floor configuration parameter on the basis of the past value of an estimated value of the floor configuration parameter, a difference between the corrected desired motion and the desired motion, the corrected motion, at least either a detected value or an estimated value of an actual joint displacement, which is a displacement amount of each joint of the mobile body, the actual posture inclination, and the deformation amount associated with each ground contact portion belonging to at least the C-th node.

20. The control device for a mobile body according to Claim 19, comprising a floor reaction force detecting means for detecting or estimating an actual floor reaction force acting on each of the ground contact portions belonging to the C-th node, wherein the deformation amount detecting means estimates the deformation amount on the basis of the actual floor reaction force.

21. The control device for a mobile body according to Claim 16, wherein, each node in the tree structure has a

set weight, and regarding a B-th node, which is each node in the tree structure, if the B-th node is the leaf node, then the height of the ground contact surface of the ground contact portion, which is the leaf node, is defined as the height of the ground contact surface of the B-th node, and if the B-th node has child nodes, then a weighted mean value, which uses the weight, of the heights of the ground contact surfaces of all child nodes of the B-th node is defined as the height of the ground contact surface of the B-th node, and when these definitions apply,

the floor configuration parameter estimated by the floor configuration estimating means is a parameter that specifies a relative relationship of the heights of the ground contact surfaces of a plurality of child nodes of the C-th node.

22. The control device for a mobile body according to Claim 21, wherein, if at least one of the child nodes of the C-th node is about to float, then the floor configuration estimating means estimates the floor configuration parameter that specifies the relative relationship of the heights of the ground contact surfaces of the plurality of child nodes while retaining, at a fixed value, the relative height of the ground contact surface of the child node that is about to float.

23. The control device for a mobile body according to Claim 16, wherein the floor configuration estimating means estimates the floor configuration parameter by using a

low-pass filter to alleviate fluctuation in the floor configuration parameter.

24. The control device for a mobile body according to Claim 16, wherein

a weight for estimating a floor configuration is set on each node of the tree structure, and

if processing in which, when a predetermined type of state amount, such as a height or a floor reaction force, is associated with each leaf node in the tree structure, the state amount of each node having child nodes is defined as a weighted mean value, which uses the weight, of the state amounts of all child nodes of the node, a value obtained by subtracting a state amount of a parent node of each node from the state amount of the node is determined as a node relative state amount of the node on the node except a root node, and zero is determined as a relative state amount of the root node, is defined as the processing for relatively hierarchizing the predetermined type of state amount on each node,

if a node relative floor reaction force Fn_rel(n=1,2,...) hierarchically relativized on each node is determined on the basis of a floor reaction force Fn(n=1,2,...) acting on each of the ground contact portions, which are the leaf nodes, and when a vector (Fa1_rel,Fa2_rel,...,Far_rel) having the node relative floor reaction forces of all child nodes aj (j=1,2,...,r. r denotes the total number of the child nodes of an n-th

node) of an n-th node as its elements, which is an arbitrary node having child nodes, is represented by a linear linkage of a plurality of predetermined mutually independent vectors R(j)(j=1,2,...,r-1) that are all orthogonal to a vector (Wa1,Wa2,...,War) having the weights of all child nodes of the n-th node as its elements, a vector having a coefficient of the linear linkage as its element is defined as a node expansion floor reaction force moment Mn_exp of the n-th node, and

if a node relative height Zn_rel(n=1,2,...) hierarchically relativized on each node is determined on the basis of a height Zn(n=1,2,...) of the ground contact surface of each of the ground contact portions, which are the leaf nodes, and when a vector (Za1_rel, Za2_rel,...,Zar_rel) having the node relative heights of all child nodes aj (j=1,2,...,r. r denotes the total number of the child nodes of an n-th node) of the n-th node as its elements is expressed by a linear linkage of the plurality of the predetermined mutually independent vectors R(j)(j=1,2,...,r-1), a vector having a coefficient of the linear linkage as its element is defined as a node expansion inclination angle θn of the n-th node,

then, the floor configuration estimating means estimates the floor configuration parameter by using the node expansion floor reaction force moment Mn_exp(n=C) or the node expansion inclination angle θn(n=C) of at least the C-th node.

25. The control device for a mobile body according to Claim 24, wherein, regarding a B-th node, which is each node in the tree structure, if the B-th node is the leaf node, then the height of the ground contact surface of the ground contact portion, which is the leaf node, is defined as the height of the ground contact surface of the B-th node, and if the B-th node has child nodes, then a weighted mean value, which uses the weight, of the heights of the ground contact surfaces of all child nodes of the B-th node, is defined as the height of the ground contact surface of the B-th node, then

the floor configuration parameter includes a parameter that uses the node expansion inclination angle to indicate the relative height of the ground contact surface of each child node of the C-th node.

26. The control device for a mobile body according to Claim 24, comprising a floor reaction force detecting means for detecting or estimating an actual floor reaction force acting on each of the ground contact portions,

wherein the node operation controlling means comprises means for sequentially determining the node expansion moment on the basis of at least an actual floor reaction force of each of the ground contact portions, and a means for sequentially determining the node expansion inclination angle by multiplying the determined node expansion moment by a predetermined matrix, and estimates a new floor configuration parameter on the basis of the

determined node expansion inclination angle and the past value of an estimated value of the floor configuration parameter.